FOOD OF THE SEA-STAR ASTROPECTEN ARTICULATUS[1]

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It has long been recognized that most sea-stars are carnivorous, devouring whatever living and dead animals they come upon (Hyman, 1955). They have interested biologists because of their depredations on beds of oysters, clams, and mussels in many parts of the world. This concern has centered on the Asteriidae and other asteroids that possess suckers on flexible arms; in these forms, the prey is held or opened by the arms and digestion begins with the stomach everted. The mechanism by which such starfishes successfully attack bivalves has received much attention.

Sea-stars that do not possess suckers on their podia, or long flexible arms, must rely on swallowing their food whole and digesting it internally. This method of feeding is employed by sea-stars of the genus *Astropecten* (Hyman, 1955). Most members of this widespread genus live more or less buried in sandy bottoms, where they ingest large numbers of sand-dwelling animals. Eichelbaum (1910) and Kisch (1958) have reported on the food of *Astropecten irregularis* from northwestern Europe, Hamann (1889) recorded the food of *A. aurantiacus* from the Mediterranean, and Caracelles and Parodiz (1938) reported on molluscs recovered from the stomach of *A. cingulatus* from the Argentine coast. A large portion of the food of these species consists of shelled molluscs. Because organisms are swallowed whole and their shells remain after the soft parts have been digested, the stomach contents of such sea-stars can be analyzed to determine what species have been devoured.

This report discusses the food of *Astropecten articulatus*, a common species off the southeastern coast of the United States.

Materials and Methods

Through the cooperation of local fishermen, 124 sea-stars were obtained from the trawler "MITZI KAY" which operates from Hatteras, North Carolina. They were collected at 4 to 7 fathoms from a sand bottom near Ocracoke Inlet, North Carolina, on January 13, 1959.

The sea-stars were identified as *Astropecten articulatus* (Say) after a careful study of specimens and taxonomic literature dealing with this genus. The purple and orange coloration of living specimens gradually faded on exposure to preservative fluids or light. Because the distribution of spines on the supramarginal plates is of primary importance in the separation of species in this genus, the virtual absence of any supramarginal spines made their identification difficult. However,

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another collection from the same area in late June revealed supramarginal spines on a majority of specimens, in a confusing variability of position. It is well recognized that *A. articulatus* is a variable species, and that supramarginal spines usually develop with increasing age in this group (Verrill, 1915; Döderlein, 1917).

To expose the stomach and its contents, the oral surface was opened by separating the plates along the ambulacral grooves. The contents, often including the thin stomach wall so as to collect any small shells hidden in its folds, were carefully removed. Usually the stomach contents included a sizeable amount of sand, as well as small gastropods, pelecypods, and other animals. These were separated and sorted with the aid of a binocular dissecting microscope.

Extensive use has been made of the mollusc collection of the United States National Museum for comparison and identification of specimens. We wish to thank Drs. H. A. Rehder and J. P. E. Morrison for their generous assistance in the identification of molluscs, and Dr. C. E. Cutress for his assistance in locating *Astropecten* specimens and literature.

Results and Discussion

Of 124 *Astropecten articulatus* stomachs examined, only four were empty. Many contained the remains of a large number of animals. On the average, each stomach contained approximately twelve organisms. The maximum number was 53, two contained 46 each, and nine had 30 or more animals. These numbers exceed the maximum number of organisms recovered from *A. irregularis* by Eichelbaum (1910) or from *A. aurantiacus* by Hamann (1889), and compare favorably with those cited by Kisch (1958) for *A. irregularis* from the coast of France. *Astropecten articulatus* is indeed a voracious predator on the inhabitants of the sand bottom community.

Many of the animals recovered were in a surprisingly fresh condition. The soft parts of recently ingested prey were frequently still intact; for example, the eyes of some gastropods could be seen through their transparent shells. Many gastropods retained the operculum, which often aided in identification. Kisch (1958) noted that certain gastropods protected by an operculum may survive more than 48 hours in the stomach of an *Astropecten*. From the stomach of *A. irregularis*, he was able to supply fresh specimens for the description of the soft parts of one gastropod (Fretter, 1956). Similarly, many organisms in fresh condition were recovered from *A. articulatus*. Some of these same species are only infrequently encountered in inshore collections. The ectoproct bryozoan, *Discoporella doma*, recovered from one sea-star still bore the characteristic, long, slender vibracula on its surface. Long-dead colonies of this stony bryozoan have been collected in shallow inshore sand in this region, but they typically lack vibracula and show the effects of considerable abrasion, as described by Maturo (1957).

A total of 91 species was represented in the stomachs examined. This aggregate contains two ectoproct bryozoans, two polychaete annelids, eleven arthropods, three echinoderms, fifty-two gastropods, four scaphopods, and seventeen pelecypods. The most abundant species were the small gastropods, *Actaeocina candei*, *Natica pusilla* and *Olivella mutica*. Together these three species account for over 60% of the animals recorded. However, the decapod crustaceans re-

TABLE I

Animals recovered from stomachs of 124 Astropecten articulatus *off Ocracoke Inlet, N. C. January, 1959*

Species	No. of specimens recovered	No. of sea-stars involved
Ectoprocta:		
Discoporella doma (Orbigny)	1	1
Schizoporella unicornis (Johnston)	1	1
Annelida:		
Unidentifiable remains	1	1
Spiochaetopterus oculatus Webster tube	1	1
Arthropoda:		
Cumacea:		
Cyclaspis varians Calman	3	2
Ostracoda:		
Pontocypris edwardsi Cushman	3	2
Pseudocytheretta edwardsi Cushman	14	9
Sarsiella sp.	3	2
Decapoda:		
Sicyonia brevirostris Stimpson	2	2
Crangon septemspinosum Say	3	3
Pagurus annulipes (Stimpson)	1	1
Pagurus corallinus (Benedict)	3	3
Ovalipes ocellatus (Herbst)	13	13
Persephone punctata (Linné)	1	1
Pinnixa sp. juvenile	1	1
Echinodermata:		
Asteroidea:		
Astropecten articulatus (Say)	5	5
Echinoidea:		
Mellita quinquiesperforata (Leske)	15	12
Ophiuroidea:		
Ophiophragmus wurdemanni (Lyman)	1	1
Mollusca:		
Gastropoda:		
Vitrinella beaui Fischer	2	2
Vitrinellidae	1	1
Caecum carolinianum Dall	14	12
Caecum cooperi S. Smith	1	1
Caecum pulchellum Stimpson	19	18
Alaba adamsi Dall	38	20
Finella cerithioides Dall	44	22
Adeorbis supranitidus Wood	12	11
Janthina globosa Swainson	1	1
Epitonium rupicolum Kurtz	2	2
Epitonium multistriatum Say	2	2
Sigatica carolinensis Dall	2	2
Sigatica semisulcata Gray	4	3
Natica pusilla Say	357	89
Anachis iontha Ravenel	5	3
Anachis obesa C. B. Adams	16	14
Anachis ornata Ravenel	8	5
Anachis sayana Rehder	1	1
Mitrella lunata Say	13	11
Nassarius trivittatus (Say)	2*	2
Oliva sayana Ravenel	1*	1
Olivella mutica Say	90	42

* Species represented only by long-dead shells.

TABLE I.—*Continued*

Species	No. of specimens recovered	No. of sea-stars involved
Terebra dislocata Say	1*	1
Niso interrupta Sowerby	2	2
Melanella subcarinata Orbigny	2	2
Rubellatoma rubella Kurtz and Stimpson	5	5
Rubellatoma elata Dall	1	1
Kurtziella limonitella (Dall)	4	4
Brachycythara biconica C. B. Adams	1	1
Mangelia atrostyla Dall	3	3
Mangelia oxia Bush	12	11
Mangelia sp. A	5	5
Mangelia sp. B	6	5
Mangelia sp. C	1	1
Mangelia sp. D	1	1
Cerodrillia sp.	2	2
Turridae	1	1
Acteon punctostriatus C. B. Adams	15	9
Rhizorus oxytatus (Bush)	5	4
Acteocina candei Orbigny	438	57
Cylichnella bidentata (Orbigny)	41	30
Turbonilla (*Turbonilla*) *nivea* (Stimpson)	1	1
T. (*Chemnitzia*) *aequalis* (Say)	17	14
T. (*Pyrgiscus*) *caroliniana* Tuomey and Holmes	1	1
T. (*Pyrgiscus*) *elegantula* Verrill	5	4
T. (*Pyrgiscus*) *areolata* Verrill	10	9
T. (*Pyrgiscus*) *interrupta* (Totten)	35	24
T. (*Pyrgiscus*) *mighelsi* Bartsch	1	1
Odostomia (*O.*) *modesta* (Stimpson)	3	2
O. (*Chrysallida*) *seminuda* C. B. Adams	4	2
O. (*Menestho*) *impressa* Say	2*	1
Cavolina longirostris Lesueur	2	2
Scaphopoda:		
Cadulus carolinensis Bush	9	7
Dentalium occidentale Stimpson	13	9
Dentalium eboreum Conrad	3*	3
Dentalium sowerbyi Guilding	5	5
Pelecypoda:		
Nucula proxima Say	1	1
Anadara ovalis (Bruguière)	1	1
Aequipecten gibbus (Linné)	2	2
Anomia simplex Orbigny	3*	3
Phacoides (*Parvilucina*) n. sp.	11	10
Bornia longipes Stimpson	21	15
Mercenaria campechiensis (Gmelin)	1	1
Chione intapurpurea Conrad	5	5
Gouldia cerina C. B. Adams	2	1
Macrocallista maculata (Linné)	4	2
Dosinia discus Reeve	3	3
Tellina americana Dall	2	2
Tellina sp.	1	1
Strigilla mirabilis Philippi	1	1
Ervilia concentrica Gould	7	5
Corbula swiftiana C. B. Adams	3	3
Pandora arenosa Conrad	14	6

covered probably represent a volume of digestible tissue equal to or greater than that contained in the above-mentioned gastropods. Legs, chelae, and entire bodies of the portunid, *Ovalipes ocellatus*, constituted the greatest portion of this decapod fraction. All species identified from *Astropecten articulatus* stomachs are listed in Table I, with the number of specimens of each and the number of sea-stars involved.

Although the echinoids and certain of the pelecypods were represented by juvenile specimens, the great majority of organisms collected from stomachs were adults, near the maximum size attained by each species. Exceptions to this generality include young sand-dollars, *Mellita quinquiesperforata* (less than 10 mm. in diameter), and juvenile clams, *Chione intapurpurea* and *Macrocallista maculata* (less than 6 mm. in length). Most of the other molluscs recovered were of a similar, minute size, being less than 6 mm. in length. Of the three most abundant species in this collection, *Natica pusilla* and *Acteocina candei* averaged about 3 mm., and *Olivella mutica* averaged about 4 mm. in length.

Several molluscs in this collection have not been taken in the inshore waters of the region. Notable examples are *Natica pusilla, Sigatica semisulcata, Adcorbis supranitidus, Alaba adamsi, Finella cerithioides* and *Acteocina candei* among the gastropods; the new species of *Phacoides, Macrocallista maculata, Pandora arenosa* and *Corbula swiftiana* among the pelecypods; and *Cadulus carolinensis* among the scaphopods.

In a few cases, indicated by an asterisk in Table I, shells were recovered which showed signs (discoloration, worn broken edges) that they were not fresh. It seems likely that these shells came from fossil or sub-fossil deposits in the area, particularly for those species which are not represented alive in the area today. This applies, for example, to *Nassarius trivittatus*, the New England Nassa, which has not been collected alive south of Chesapeake Bay. (Pearse, Humm and Wharton (1942) confused this species at Beaufort, N. C., with a form of *N. vibex*.) Evidently, *Astropecten articulatus* ingests mollusc shells whether they are occupied by the original inhabitant or not. Of course, some of these dead shells may have contained hemit crabs (*Pagurus* species) and thus have contributed to the sea-star's nutrition.

Several other species which appear to be out of place among the bottom fauna are represented. The purple sea-snail, *Janthina globosa*, and the pteropod, *Cavolina longirostris*, are typically pelagic, the former being carried about near the surface by its prey or by a foam raft of its own making, and the latter by active swimming. With death, these species fall to the ocean floor where they can be eaten by *Astropecten articulatus* or any other scavenger. In addition, a number of fish scales were contained in the stomachs. While some could have been ingested while the starfish were in the fish trawl, most fish scales had undoubtedly been picked up from the sand bottom.

Astropecten articulatus could be called cannibalistic in view of the presence in their stomachs of small specimens and fragments of the same species. Most of these had been ingested as fragments of broken sea-stars, perhaps left by the passage of other trawlers, although a few small specimens had been swallowed entire by larger starfish. Kisch (1958) noted such cannibalism in *Astropecten irregularis* off the coast of France, and the ingestion of other echinoderms is not an unusual

practice in the genus *Astropecten*. According to Eichelbaum (1910), other echinoderms compose a major part of the diet of sea-stars of the genus *Luidia*.

Because the gastropod genera *Niso* and *Melanella* are recognized as ectoparasites of echinoderms, the occurrence of specimens of each raised the question of whether these species might be parasitizing *A. articulatus*. However, it should be noted that the asteroid *Luidia clathrata*, the echinoids *Mellita quinquiesperforata*, *Encope emarginata*, and *Moira atropos*, and the holothurian *Thyone briareus* are all present in this immediate area. Unless one can observe the feeding activities of these gastropods, no decision can be made as to which echinoderm species they parasitize.

Kisch (1958) listed sixteen molluscs recovered from *Astropecten irregularis* that represented new records for the area collected (Roscoff, France). The most notable novelties among the molluscs of the present collection are a new pelecypod (to be described elsewhere), and *Sigatica semisulcata*, a rare gastropod previously reported only from the west coast of Florida. Because the taxonomy of turrid gastropods is in a state of confusion, additional undescribed species may be represented in the Turridae of this collection.

Many of the molluscs represented have been treated in the account of species dredged by the United States Fish Commission steamer "ALBATROSS" in the Cape Hatteras region in the 1880's (Bush, 1885). In the publication, several species were described as new from this area. Their appearance in this collection serves as an indication of the value of including an analysis of starfish stomach contents among sampling methods for benthic organisms. From all indications, *Astropecten articulatus* appears to be a non-selective feeder, its stomach contents reflecting the faunal composition of the offshore sand bottoms frequented by it. Indeed, this species can serve the marine biologist as a convenient tool for the study of bottom fauna, as a dredge which samples indiscriminately the abundant minute animals that live in sand.

This generalization evidently applies equally well to other species of *Astropecten* that inhabit sand. If one compares the lists of food organisms recovered from the stomachs of various species of *Astropecten* in different parts of the world, a striking similarity becomes evident. There is a close correspondence in the types of molluscs represented, exemplified by the presence of representatives of the same genera, from widely separated localities. Making allowances for different interpretations of the latitude of certain genera, one finds that the principal difference in these lists of molluscs is at the species level. These specific differences are essentially geographic variations on a basic form, that reflect the geographic affinity of a particular sand-bottom fauna. Therefore, the food organisms recovered from stomachs of different species of *Astropecten* probably are comparable samples of the sand-dwelling fauna of their respective regions. The genus *Astropecten* may serve as a tool for comparative studies of sand-bottom communities in different parts of the world.

Summary

The stomach contents of 124 *Astropecten articulatus* have been identified and discussed. This starfish ingests great numbers of small sand-dwelling organisms. Ninety-one species of invertebrates were recovered, of which 73 were molluscs. The gastropods *Acteocina candei*, *Natica pusilla* and *Olivella mutica* comprised

over 60% of the animals recovered. *Astropecten articulatus* apparently ingests whatever animals or shells it encounters. Because it effectively samples the fauna of offshore sand bottoms, its use is recommended as a collection tool for the study of this community.

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